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ORIGINAL RESEARCH

CHANGES IN PELVIC TILT DURING THREE DIFFERENT RECIPROCAL STANCE POSITIONS IN PATIENTS WITH SACROILIAC JOINT REGIONAL PAIN

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ABSTRACT

Purpose: Essential to the successful management of patients with sacroiliac joint pain (SIJP) is understanding how these joints move. The innominates tilt together in the same direction with symmetrical activities (i.e. forward-bending) but move opposite of one another when performing asymmetrical activities (i.e. walking). How they move in patients with SIJP is unknown. The purpose of this study was to examine inter-innominate movement (tilt) when assuming three different stance positions to describe how the innominate bones move in those with and without SIJP.

Study type: Observational Cohort Study

Methods: Twenty-eight participants were classified into two groups; SIJP with low back pain (LBP), and no SIJP or LBP. SIJP participants were further classified into groups with left or right pelvic tilt. Pelvic tilt was measured during neutral standing and in both left-sided and right-sided reciprocal stance, with a full-stride (one hip fully flexed the other fully extended) and in a half-stride position, which mimic the double-stance phase of gait. A repeated measure ANOVA assessed for differences between Groups (Level, Left or Right Pelvic Tilt), stance side position (left/right), and stride length (full/half).

Results: The was a significant Group main effect ($F [2, 25] = 130.2$, $p < 0.0001$), and a significant Side main effect ($F [1, 25] = 429.7$, $p < 0.0001$), qualified by a significant Side x Group interaction ($F [2, 25] = 19.9$ $p < .0001$). Follow-up comparisons showed that pelvic tilts for right and left stance were significantly different ($p < 0.05$) for each group (Level, left and right pelvic tilt). For the right stance condition, all groups were significantly different from each other ($p < 0.05$). For the left stance position, the right pelvic tilt and level pelvic tilt means were not different from each other ($p > 0.05$), but each was different from the mean for the left pelvic tilt group ($p < 0.05$).

Conclusions: When assuming an asymmetrical stance position, the innominates tilt opposite of each other in those without SIJP. In patients with SIJP they behave in the normal fashion in one asymmetrical stance position but not the other. Instead of tilting opposite, as expected, the innominates remain symmetrical, dependent on the side of the presenting pelvic tilt.

Level of Evidence: 2b

Keywords: Innominate tilt, low back pain, sacroiliac joint

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INTRODUCTION

Low back pain (LBP) is a common problem that creates functional disability in both athletes and non-athletes alike. An often under-diagnosed cause of recurrent LBP is pain arising from the sacroiliac joints.[1,2] A likely reason for not recognizing sacroiliac joint pain (SIJP) in LBP patients is that individual tests are not very reliable for discerning sacroiliac joint movement.[3-6] This is an expected finding since little is known regarding how the sacroiliac joints of the pelvis move. Determining how the sacroiliac joints move in those with SIJP compared to those without SIJP would give therapists direction in both the assessment and the management of patients with LBP with contributions from the sacroiliac joints. A greater understanding of how the two joints of the hemi-pelvis move could potentially impact the treatment of femoroacetabular impingement. Pelvic posture and kinematics influence acetabular orientation and are involved in the pathomechanics of femoroacetabular impingement.[7,8]

While numerous researchers have examined *how much* the sacroiliac joint moves,[9-14] which is very little, [9-14] few have examined just *how* the sacroiliac joints move in those with SIJP.[15,16] The most often used in-vivo model for studying normal sacroiliac joint motion is observing the relative movement of the two innominate bones (inter-innominate motion) during reciprocal stance positions.[13,14,17-19] During normal standing, the two innominates mirror each other, each having the same amount of innominate tilt.[17,20,21] When assuming a reciprocal stance position, a double weight-bearing position where one hip is maximally flexed the other extended, the two innominates tilt in opposite directions of each other, the flexed hip anterior the extended hip posterior.[13,14,19] This kind of innominate tilt is contrary to those with a leg length difference in which those with a long leg have a high innominate, with both ASIS and PSIS appearing higher on one side compared to the opposite or low side.[22] The first study describing this phenomenon of opposite or antagonistic innominate tilt was by Pitkin and Pheasant.[18] Subsequent researchers have also examined inter-innominate movement when assuming a reciprocal stance position and found similar results.[13,14,17,19] The purpose of this study was to examine inter-innominate movement (tilt) when assuming three different stance positions to describe how the innominate bones move in those with and without SIJP. The research hypothesis was that participants with SIJP would have altered innominate movement during reciprocal stance positions compared to those without SIJP. Understanding the difference between how the two innominates move in those with versus those without SIJP will provide therapists important information that will help in the management of those with LBP from SIJP and perhaps also those with femoroacetabular impingement.

METHODS

Twenty-eight participants, with and without LBP, were gathered from Maryville University students, and the greater St. Louis community. The Institutional Review Board at. Maryville University approved this study protecting the rights of all included or excluded. Participants were asked to review and sign an informed consent. The cohort's mean age was 23.0; range 18-24, mean height = 172.5 cm.; mean weight = 72.5 kg, mean BMI = 24.1; 17 females and 11 males. Eligible participants in the LBP group were those who had unilateral low back located principally around the posterior superior iliac spine (PSIS).

After signing the informed consent, participants were screened for inclusion and exclusion criteria. The inclusion criteria for SIJP included: a chief complaint of unilateral PSIS pain. SIJP was confirmed by having a total score of at least four of six items on Kurosawa's diagnostic scoring system; with a finding of a positive one-finger test, groin pain, pain while sitting, positive sacroiliac shear test, and tenderness of PSIS or the sacrotuberous ligament (Specificity = 86.4; Sensitivity = 90.3).[23] The person performing these tests did not know who had LBP and who did not have LBP. Tests were also performed to assess the putative direction of left versus right innominate tilt, including assessing for uneven PSIS's while seated, the supine-long sitting test, and the prone knee flexion test.[21,24 25-28] The mean LBP of participants was 2.3/10, which is characteristic of those with mechanical LBP (1.2 - 4.0/10 using the Numeric Pain Rating Scale).[29] All participants were first assessed for SIJP and then categorized into one of two groups, those with LBP and SIJP and those without SIJP and without LBP. The SIJP group was further classified into either the left pelvic tilt or a right pelvic tilt group from the results of the tests to putatively determine innominate tilt direction.

Exclusion criteria included: lower extremity surgery within the prior three months, or current lower extremity injury. Exclusion criteria also included: signs of nerve root involvement including a positive straight leg raise test, myotomal weakness, absent deep-tendon-reflexes, or reported greater LBP with posterior/anterior pressure to the spinous processes of the lumbar vertebrae compared to the sacral sulcus, previous back surgery, or currently receiving therapy for LBP. Finally, participants were excluded if they had a history of fracture or surgery in either lower extremity, or if they reported they had a leg length difference or had clinical or radiographic confirmed leg length discrepancy or scoliosis that could affect the findings of the study. One participant was excluded because of having greater lumbar pain, as exhibited by greater pain with posterior/anterior pressure than sacral sulcus pressure.

Measuring Innominate Tilt

Three different stance positions were used to measure changes in innominate tilt. The three different stance positions were used to achieve both a resting (neutral) position and positions of maximal hip flexion on one side and maximal hip extension on the other side (bilaterally), duplicating previous sacroiliac joint research.[10,13,14] The first was a neutral standing position with the feet placed shoulders width apart; the other two positions were a left and a right reciprocal stance where they stood in a position where one hip was flexed while the other was extended as far as possible without losing their balance (Figure 2). The stance position was operationally defined by the maximally flexed hip, so a maximally flexed left hip with a maximally extended right hip was a left reciprocal stance. The testing sequence of the reciprocal stance positions was randomly determined by the flip of a coin with each person.

The PALpation Meter device (Performance Attainment Associates, Lindstrom, MN, USA) was used to measure sagittal (anterior/posterior) innominate tilt and PSIS level (frontal tilt). The PALpation Meter has previously been shown to have excellent intra-rater reliability for assessing sagittal innominate position (ICC: 0.89-0.96).[30] The PALpation Meters measurement scale, when attempting to measure innominate tilt, was too narrow to assess sagittal innominate tilt in many of the participants when standing in their reciprocal stance position, so in its place frontal plane horizontal heights using the PSIS's as landmarks with the PALpation meter (pelvic tilt) was assessed instead. Assessing PSIS heights is a commonly used clinical method to determine the direction of innominate tilt.[22,31,32] Drerup and Heirholzer showed that the level of PSIS's can be used as indicators for pelvis movements, they found a near perfect correlation between bony landmark levels and pelvis movement measured with a rasterstereographic device an introducing artificial pelvic tilts.[33] Walker et al demonstrated the reliability (ICC = .84) of the pelvic calipers for measuring innominate tilt.[34] Also the construct validity of the pelvic calipers were demonstrated in a previous study where uneven horizontal PSIS heights measured in standing, in those without leg length disparity, were able to predict differences in sagittal plane tilt between the left and right innominate bones in those with SIJP, with the inferior PSIS side indicating a relative posterior tilt and the superior PSIS side a relative anterior tilt.[21]

Prior to testing two small pilot studies were performed, one to confirm the relationship between sagittal to frontal innominate tilt, and the second to assess reliability. To confirm the relationship between sagittal to frontal innominate tilt a subsample of those with and without SIJD were compared. In those without a leg length disparity, a low PSIS suggests a posterior innominate tilt, while a high PSIS suggests an anterior innominate tilt.[22,32] An anterior innominate tilt was defined as positive direction of movement while a posterior tilt was a negative direction of movement. Six participants, three with and three without SIJP were assessed for sagittal innominate tilt (Mean BMI = 22.7). In sacroiliac joint dysfunction, one innominate tilts anterior relative to the opposite posterior tilted innominate.[21] All three participants without SIJP had a horizontally even or level pelvis during neutral stance with near perfect symmetry between the left and right PSIS's heights with a difference of just over 1°. When measuring the amount of sagittal tilt during neutral stance, the degree of left innominate tilt equaled the right innominate tilt, suggesting pelvic symmetry. The measured difference during neutral stance in tilt between the left and right innominate in all three participants was 1º, suggesting that the posterior PSIS measurements reflected the direction of sagittal innominate tilt in those without SIJP. When assuming a reciprocal stance position, the superior PSIS side demonstrated an anterior tilt (a positive inclination where the ASIS was lower and PSIS was higher when compared to the opposite side), while the inferior or caudal PSIS side demonstrated a posterior tilt.[22] The mean difference, when assuming a reciprocal stance, between the left and right PSIS was 20°. Thus, showing evidence that left to right horizontal PSIS inclination measurement could predict sagittal innominate tilt direction in those without SIJP (as long as they did not have a leg length disparity).

In the sub-sample of participants with SIJP, the side of the superior PSIS had a more anteriorly tilted innominate (mean of +17.3º of anterior tilt) when compared to the opposite inferior PSIS side (a mean anterior tilt of +1.9º). The mean difference between left and right PSIS was 8.5º Thus, the results showed that using posterior PSIS measurements can serve as a proxy measurement for sagittal innominate tilt in those with SIJP.

Frontal plane inclination (e.g. Pelvic Tilt) of the left and right PSISs were assessed by an experienced physical therapist (MTC; 40 plus years of clinical experience). Few, if any, studies have carefully examined the intratester reliability of assessing PSIS heights. Moreover, while recent systematic reviews[35,36] showed that palpating PSIS having slight to moderate inter-tester reliability, all of the studies had serious design problems from using examiners with very little clinical experience (e.g. students),[37-39] improper position (palpating PSIS position while lying prone),[37,40-42] using very small sample sizes,[3,37,43-45] or employing asymptomatic populations.[43,44,46] Thus, to ensure reliability for this study, intra-tester reliability of PSIS palpation and measurement was assessed on ten participants. The PSIS were palpated with a circular motion and then placing thumb pressure underneath each of the bony prominences of PSIS's.[30] Once assured of the thumb's position was under the bony prominence of the PSIS's a separate investigator placed the tips of the caliper exactly on top of the ulnar aspect of the thumbs and measured the innominates position Figure 1The investigator palpating the PSIS was blinded

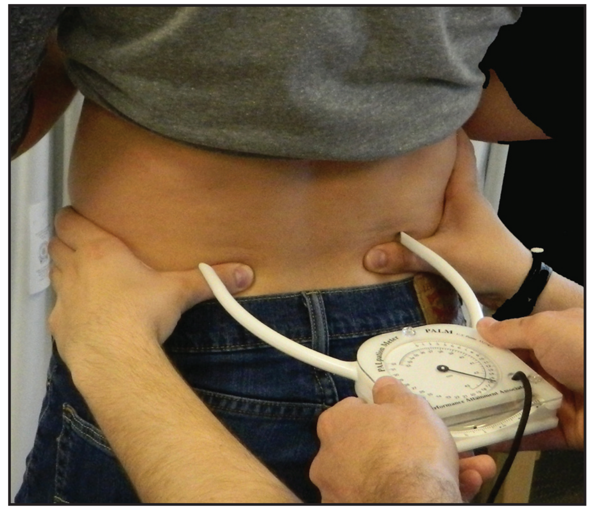

Figure 1. *Method used to Measure Horizontal PSIS difference with the PALmeter caliper (Palmeter, Performance Attainment Associated, St. Paul, MN, USA).*

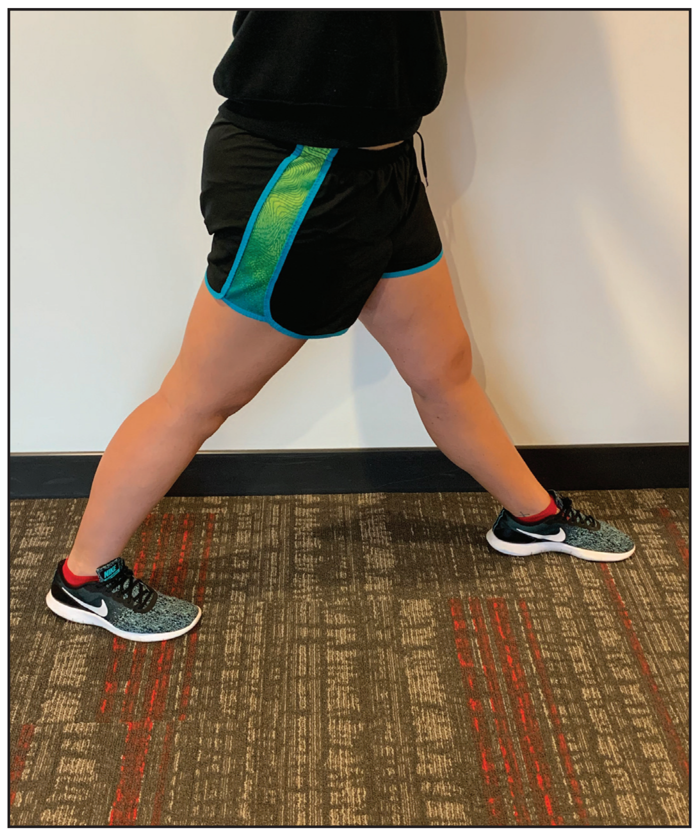

Figure 2. *Example of reciprocal stance position during which measurements were taken.*

to the measurements taken. The ICC (3,1) = .96 (CI_{95}: .91-.98) were excellent. Minimal detectable change (MDC_{95}) = .86 degrees for pelvic tilt was determined using the formula for the standard error of the measure (SEM) = (baseline pooled standard deviation * √1-.96) * 1.96 *√2.

For testing in this study, a left pelvic tilt was defined *a priori* as an inferior or caudal position of the left PSIS compared to the right PSIS of greater than 4° which is denoted as negative (-), and a right pelvic tilt as an inferior position of the right PSIS compared to the left PSIS of greater than 4° which is denoted as positive (+). The 4° difference was established using mean measurement values from a previous study that examined innominate tilt in patients with SIJP.[21] Thus, three different pelvis conditions were possible: no SIJP (level pelvic tilt) where the left/right PSIS are level in the same frontal plane, and SIJP with left pelvic tilt or SIJP with right pelvic tilt. All SIJP patients were classified as either a left (-) or a right (+) pelvic tilt. To control for the possibility that a frontal plane pelvic list could influence the measurements, PSIS's were assessed only during simulated double limb support phase of gait. The pelvis naturally drops during the mid-swing phase of single limb support but not during the double limb support phase of gait.[47]

The assessment of innominate tilt was performed while standing, participants were asked to stand with their feet shoulder-width apart. Participants were asked to take a big step backward, without losing their balance, so that one hip was maximally flexed, and the other hip maximally extended with both knees extended and the trunk neutral with weight equally distributed. The stance distance from the heel on the hip flexion side to the toe on the extended hip side was measured. To assess if the amount of stance (e.g. the degree of hip flexion and extension measured in) affected pelvic tilt, all were placed in a ½ stance position. The ½ stance position was determined by halving the measured full-stride stance position. Participants were placed in a half-stance position so that one hip was half-flexed while the other hip was half-extended. Three measures were recorded for each ½ stance positions. The participants then repeated the full stance and ½ stance process on the opposite side. Measurements were repeated using the exact same procedures. Therefore, all participants were measured in neutral and then in half-stance and full stance for both reciprocal stance positions. The investigators taking the pelvic tilt measures were blinded to those who had LBP and SIJP and who did not.

Data Analysis

Data were analyzed using the open source program, R.[48] Measurements of innominate tilt were obtained from each participant and summarized using descriptive statistics. An ICC (3,1) was used to assess the intra-rater reliability for pelvic tilt measures on the first 10 participants in this study. Data were analyzed using a three-way between (Group) and within (Length, Side) repeated measure ANOVA (3x2x2). The dependent variable was innominate tilt measured in degrees. The independent variables consisted of Group (level pelvic tilt, left pelvic tilt, right pelvic tilt), Length (half or full stance), and Side (left stance, right stance). Follow-up comparisons of means were alpha adjusted using the Holm-Bonferroni method to adjust for family-wise error when making multiple comparisons. Residuals were checked for normality, and variance-covariance matrices checked for homogeneity. Given some violations, the inferences were verified using randomization tests. Confidence intervals [CI] were all reported as 95% CI's.

RESULTS

Twelve participants were classified into the no SIJP (Level Pelvic Tilt) group and 16 in the SIJP group, eight with a left pelvic tilt and eight with a right pelvic tilt. The dependent variable (pelvic tilt) residuals were normally distributed (all Shapiro-Wilk tests, $p > .05$). Tests for homogeneity of the variance-covariance matrix (M test, x^2 (df = 20) = 55.1, $p < .001$) indicated violation of this assumption.

During neutral standing the mean pelvic tilt without SIJP was 1.1° [CI .03: 2.2], while those with SIJP had a mean pelvic tilt of -7.2° [CI -8.3: -6.0] for left pelvic tilt (left low PSIS) and +6.0° [CI 4.8: 7.2] for right pelvic tilt (right low PSIS) (Figure 3.) During a full reciprocal stance, those without SIJP assuming a left stance had a mean pelvic tilt of +12.4° [CI 10.8: 14.0] while assuming a right stance the mean was -10.2° [CI -11.8: -8.6]. **(**Figure 4**)** In those with SIJP with a

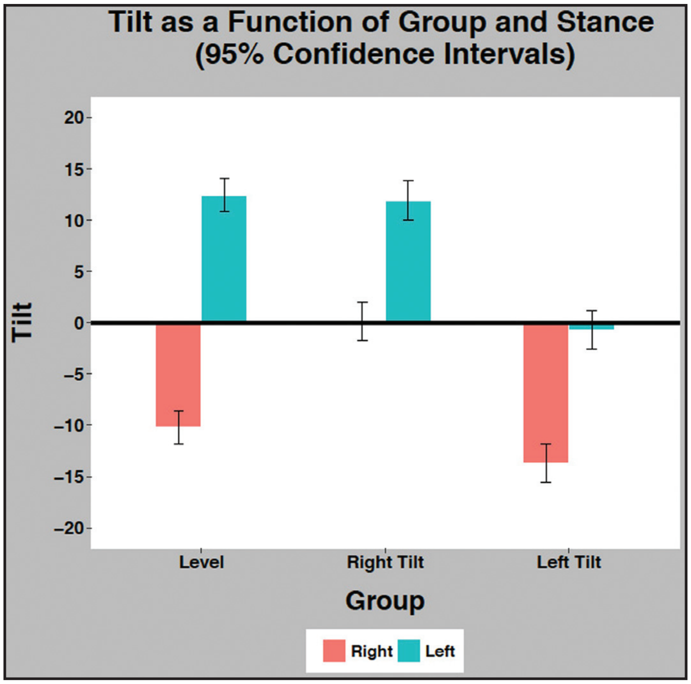

Figure 3. *Bar graph showing the mean amount of pelvic tilt by Group (Level = No SIJP; Left Tilt & Right Tilt) versus Side (Left (left hip flexed;right hip extended) or Right (right hip flexed; left hip extended) Reciprocal stance position).*

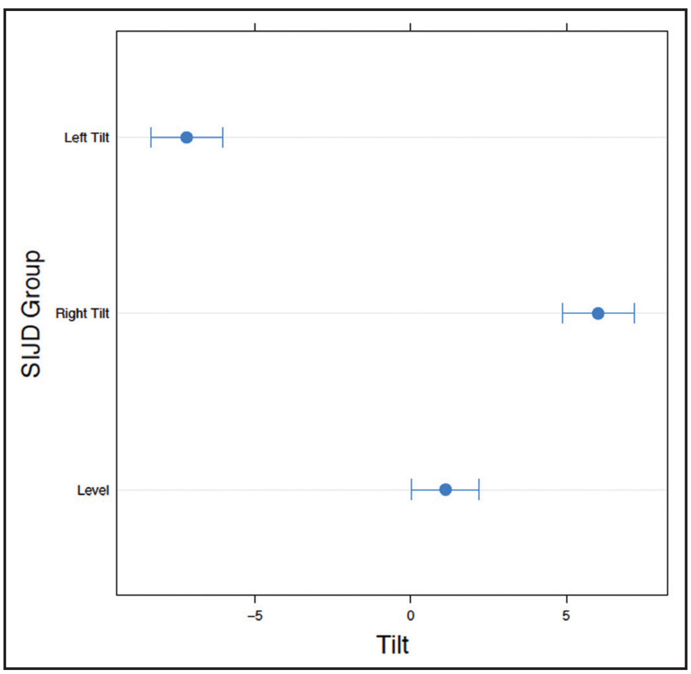

Figure 4. *Graph showing the means for pelvic tilt by Group (Level = No SIJP; Left Tilt, Right Tilt) in Neutral stance position.*

left pelvic tilt and left stance the mean pelvic tilt was -0.7° [CI -2.6: 1.2] while with a right stance the mean was -13.7° [-15.6: -11.8]. For those with SIJP with a right pelvic tilt during a right stance mean pelvic tilt

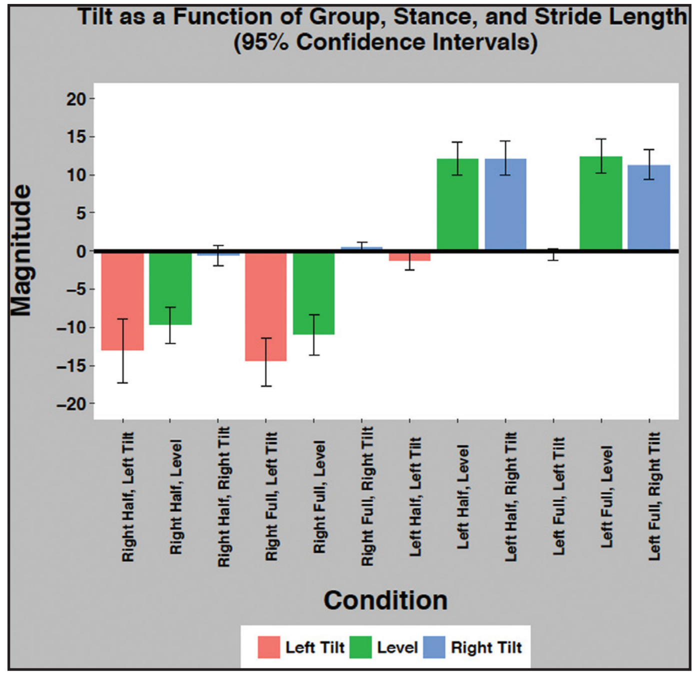

Figure 5. *Bar graph showing means for pelvic tilt as a function of Group ((Level = No SIJP; Left Tilt & Right Tilt), Stance (Left/Right), and Stride Length (1/2 or full stance).*

was +0.13° [CI -1.8: 2.0] while during a left stance the mean pelvic tilt was +11.9° [CI 10.0: 3.8] (Figure 3**).** The half-stride stance position results were similar to the full-stride position (Figure 5).

The repeated measure ANOVA found a significant Group main effect (F [2, 25] = 130.2, p < .0001), and a significant Side main effect (F [1, 25] = 429.7, p < .0001), qualified by a significant Side x Group interaction (F [2, 25] = 19.9 p < .0001) (Figure 3). Follow-up comparisons within groups using the Holm-Bonferroni correction procedure indicated that mean pelvic tilts for right and left stance were significantly different (p < .05) for each group (Level, right pelvic tilt, and left pelvic tilt). Within the right stance condition, all groups were significantly different from each other (p < .05). Within the left stance condition, the right pelvic tilt and level pelvic tilt means were not different from each other (p > .05), but each was different from the mean for the left pelvic tilt group (p < .05).

Because the data did not satisfy the homogeneity of variance-covariance matrices assumption, the inferences were verified using a randomization test, which does not require this assumption. For each of 10,000 trials, the factor labels (e.g., Level, Right

Table 1. *Descriptive Statistics for Groups.*

Stance Position	Groups	Mean	Std. Deviation	N
Neutral Stance *(Left and Right hip in anatomical position)*	Level (No SIJP)	1.1°	0.33°	12
	Left Tilt (SIJP)	-7.2°	1.3°	8
	Right Tilt (SIJP)	6.0°	1.7°	8
Left Reciprocal Stance *(Left hip flexed; right hip extended)*	Level (No SIJP)	12.4°	3.2°	12
	Left Tilt (SIJP)	-0.7°	0.5°	8
	Right Tilt (SIJP)	11.9°	4.2°	8
Right Reciprocal Stance *(Right hip flexed; left hip extended)*	Level (No SIJP)	-10.2°	4.2°	12
	Left Tilt (SIJP)	-13.7°	4.2°	8
	Right Tilt (SIJP)	0.13°	0.4°	8

No SIJD = Level, where left and right PSIS are in the same horizontal plane; SIJD = Left Tilt = where left PSIS is lower than the right PSIS (negative); Right Tilt = where right PSIS is lower than left PSIS (positive); in degrees.

Stance, etc.) for the data were randomly shuffled under the assumption that factor labels are arbitrary if the null hypothesis is true. The F-ratios were calculated for each trial with the reshuffled data. Across the trials, the proportion of F-ratios for each effect that exceeded the original F ratios were tallied. If the original F-ratios are unusual under the null hypothesis, then very few of the F- ratios from the randomization test trials should exceed the original F ratios. None of the randomization test F-ratios were greater than the corresponding original F-ratios, verifying the robustness of the original results.

DISCUSSION

In those without SIJP, the results of the current study agree with results from most of the previous studies showing that the left and right innominates tilt in opposite directions when assuming a reciprocal stance position.[13,14,17,19] In the current sample, in those with SIJP, the left and right innominates tilted opposite of one another in one of the reciprocal (asymmetrical) stance positions but not in the other reciprocal stance position. Instead of tilting in opposite directions, the left and right innominate bones remained horizontally level. This type of innominate movement was dependent on the side the pelvis was tilted (left or right pelvic tilt). When those with a left pelvic tilt (where the PSIS was found lower or inferior on the left in neutral stance, often called a posterior innominate) assumed a right reciprocal stance position (left hip extended; right hip flexed) the innominate position remained the same with no change in position, and they continued to remain in this same position also when in a neutral stance position (left low PSIS, right high PSIS). However, when assuming a left reciprocal stance position (left hip flexed; right hip extended), where expecting the left PSIS to be high (anterior tilt) and the right PSIS low (posterior tilt), the two innominate bones remained horizontally level. This same coupling pattern was noted for those with SIJP that had a right pelvic tilt, but in an opposite fashion**.** This finding suggests a coupling failure of the two innominates to fully tilt opposite of one another, meaning that the innominate bone on the posterior tilted side did not fully tilt anteriorly, and on the opposite side, the anterior innominate did not fully tilt posteriorly.

That the two innominate bones remained horizontal in those with SIJP during a reciprocal stance, when they should have tilted opposite of one another, suggests that they "attempted" to complete a full opposite (antagonistic) innominate tilt, but for whatever reason could not complete it. From these results, the reason(s) for the failure of the two innominates to fully tilt opposite is unknown. Nevertheless, the results of the current study demonstrate that movement likely develops from both left and right sacroiliac joints, and that although presenting unilaterally, SIJP is not just a one-sided problem, as often suggested. Previous Osteopathic concepts regarding innominate tilt suggest that a single innominate can tilt unilaterally, where one side tilts independent (anterior or posterior) of the other side.[32] However, for this to occur the symphysis pubis would have to move much more than is anatomically possible.[10] The symphysis pubis is reported to only have 1.0-2.0 mm of motion.[49] In those without SIJP, the amount of antagonistic tilt of the left and right innominates during reciprocal stance was nearly symmetrical suggesting that the left and right innominates tilt equal yet opposite of each other. The kind of movement allows the two innominate bones to rotate together as a single unit around the sacrum,[10] moving simultaneously at both sacroiliac joints, thus sparing the amphiarthrodial symphysis pubis joint from excessive shearing movement.

The finding of pelvic obliquity (uneven ASIS or PSIS) is common in patients with SIJP.[32,50,51] When in a neutral stance for the subjects with SIJP the two innominate bones were always tilted opposite of each other, while those without SIJP were always nearly symmetrical. The mean of pelvic obliquity (pelvic tilt) found in patients with SIJP was 6.6°, when considering both sides (joints) are moving opposite of each other (thus summing both sides), this amount of movement is similar to previous studies.[10,52] Previous authors who have conducted studies attempting to identify SIJP patients using innominate asymmetry have had significant design problems,[3,53] including assessing the reliability of individual tests by themselves (yes/no) and not using information from complementary tests for feedback, as well as not integrating test results that supply the putative direction of innominate tilt (direction and side of tilt).[3,53] For example, finding of a short leg that lengthens with the supine-long-sitting test suggests a posterior innominate tilt, while the long leg suggests an anterior innominate tilt,[54] which should also agree with a finding of a lower PSIS on the same side of the shortened leg when in a seated position. If the test results don't agree, there is a likely a problem, suggesting the need for additional re-testing to confirm. So far, none of the previous SIJP studies which reported poor test reliability used this kind of recursive method.[3,53] As clinicians, using the diagnostic process, the sum of information is weighed from the patient's history as well as all of the clinical tests performed, not just information from a single test.

It is well understood that the pelvic girdle responds to muscle actions from above and below.[55] Sacroiliac problems are often the result of asymmetrical muscle imbalances in the pelvis/hip.[56] Asymmetrical muscle imbalances have been shown to be related to SIJP. Asymmetrical hip rotation, where hip rotation on one side (e.g. external rotation) is different (greater or lesser) than the opposite side, has been associated with SIJP,[57] and those with asymmetrical hip rotation have hip rotator muscle imbalances[58] van Wingerden et al. showed that the forces from the biceps femoris muscle could influence the sacroiliac joint and thus low back kinematics.[59] Vleeming et al. suggest the piriformis, gluteus maximus, and biceps femoris muscles all may influence the movement of the sacroiliac joint through their attachment to the posterior sacroiliac joint ligaments.[60] Also, the active straight leg raise test, as suggested by Mens et al., lends further support to the concept that muscle action(s) can affect sacroiliac joint kinematics. Mens et al. noted an asymmetrical straight leg raise (signifying unilateral weakness of the hip flexors) on one side in peri-partum women with SIJP, may result in an anterior "hip" rotation.[61] Similar to Mens et al. concept, a new method for assessing SIJP assessment relies on identifying pelvic muscle imbalances as a means to determine the presence and direction of innominate tilt. Many different combinations of muscle length or strength imbalances between the left and right sides of the hip/pelvis that possibly can produce an asymmetrical "pull" on the innominate bones. According to Kendall, asymmetrical muscle forces can create (strong or short muscles) or allow (weak or long muscles) a dysfunction. Thus, clinically a number of different muscle imbalances scenarios may exist creating or allowing a concomitant anterior tilt of one innominate and a posterior tilt of the opposite innominate. Thus, in clinical practice it is usually identifying the asymmetrical hip/pelvic muscle imbalance patterns that gives therapists the best information on the direction of left and right innominate tilt and therefore how to treat patients with SIJP.[62]

Limitations

In this study, the PSIS's were palpated by only one examiner with 40 plus years of orthopedic clinic experience, and high inter-examiner reliability was demonstrated. Clinicians with less experience may produce different results. Also, all of the participants BMI were all fairly low, making palpation of the PSIS easy. If the BMI of the participants had been higher in this study, the results could have been different. Also, the population used in this study was relatively young, thus the results cannot be generalized to an older population. Finally, using pelvic calipers only captures simple differences between the left and right side, and the innominate bones move in a much more complex manner. Much more research is needed to explore how these joints move.

CONCLUSION

The innominate bones tilt in an equal and opposite fashion when measured in a reciprocal stance position, depending on whether the hip is flexed or extended, but not on the amount of hip motion (length of the stance). In SIJP a coupling failure may occur where the left and right innominate bones fail to fully tilt opposite of each other and remain in a neutral (anatomic) position. Understanding how innominate motion is altered in patients with SIJP will likely improve therapist's ability to identify and treat patients with LBP from SIJP.

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